Performance analysis of Multiband - OFDM systems using LDPC coder in pulsed - OFDM modulation for UWB communications

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Abstract — **In this paper, a combined approach where low density parity check (LDPC) codes are used to reduce the complexity and power consumption of pulsed orthogonal frequency-division multiplexing (pulsed-OFDM) ultra-wideband (UWB) systems is described. The proposed system uses LDPC codes to achieve higher code rates without using convolution encoding and puncturing thereby reducing the complexity and power consumption of pulsed-OFDM system. The LDPC-pulsed-OFDM system achieves channel capacity with different code rates and has good performance in different channel fading scenarios. The pulsed OFDM system is used where pulsed signals could spread the frequency spectrum of the OFDM signal. The performance of LDPC-pulsed-OFDM system for wireless personal area networks (WPAN) is analyzed for different UWB indoor propagation channels (CM3 and CM4) provided by the IEEE 802.15.3a Standard activity committee. To establish this, a design of LDPC-pulsed-OFDM system using the digital video broadcasting-satellite-second generation (DVB-S2) standard and provide the simulation results for the different code rates supported by LDPC codes is presented.**

Keywords—**Low Density Parity Check (LDPC), pulsed orthogonal frequency-division multiplexing (pulsed-OFDM), orthogonal frequency-division multiplexing (OFDM), LDPC-pulsed-OFDM, ultra-wideband (UWB), digital video broadcasting-satellite-second generation (DVB-S2), wireless personal area networks (WPAN).**

I. INTRODUCTION

The upsurge of wireless communication devices in our lives shows no sign of languor. The growing demand for high quality media and high-speed content delivery drives the pursuit for higher data rates in communication networks. Wireless personal area networks (WPAN's) are used to convey information over relatively short distances of about 10 meters among a relatively few participants. Unlike wireless local area networks (WLANs), WPAN's connections involve little infrastructure. This allows small, power efficient, inexpensive solutions to be implemented for a wide range of devices. LDPC codes have the advantage of achieving near channel capacity for different code rates. LDPC codes are the codes that offer error detection and correction capabilities close to theoretical limit [2]. Higher code-rates can be achieved easily and hence reduce the complexity, power consumption and cost of the system implemented using LDPC codes. Also, UWB technology is used for short and medium range wireless communication networks with various throughputs including very high data rate applications. UWB communication systems use signals with a bandwidth that is larger than 25% of the center frequency or more than 500 MHz. The main issue of spectrum scarcity is overwhelmed by ultra-wideband technology. UWB communication systems have advantages, including robustness to multipath interference and inherent support for location-aware networking and multiuser access [3], [4]. UWB communications transmit in a way that doesn't interfere largely with other more traditional narrowband and continuous carrier wave uses in the same frequency band.

OFDM technique and its variations are widely used in several narrow-band systems. Pulsed-OFDM is a major UWB system that uses OFDM modulation in the UWB spectrum. The pulsation of the OFDM signal spreads its spectrum and provides a processing gain that is equal to the inverse of the duty cycle (less than 1) of the pulsed sub-carriers [1]. A pulsed-OFDM signal can easily be generated by up-sampling the output of an inverse fast Fourier transform (IFFT) module in a normal OFDM system. Also, a low-complexity receiver is achieved for the pulsed-OFDM system that exploits the spreading gain provided by the pulsation to enhance the performance of the system in multipath fading channels [1]. In this paper, we proposed an enhancement to the pulsed-OFDM system where the complexity of achieving higher data rates using convolution encoding and puncturing technique is replaced by an LDPC encoder. The new approach is a combined form of the benefits of LDPC codes, UWB and pulsed-OFDM technology. Chapter II discusses about the pulsed-OFDM signal generation and its key concepts that is used in the proposed system. Chapter III describes the proposed system model and how it reduces the complexity and power consumption when compared to Pulsed-OFDM system. Chapter IV presents the simulation results of the proposed system for channel models CM3 and CM4 with different code rates.

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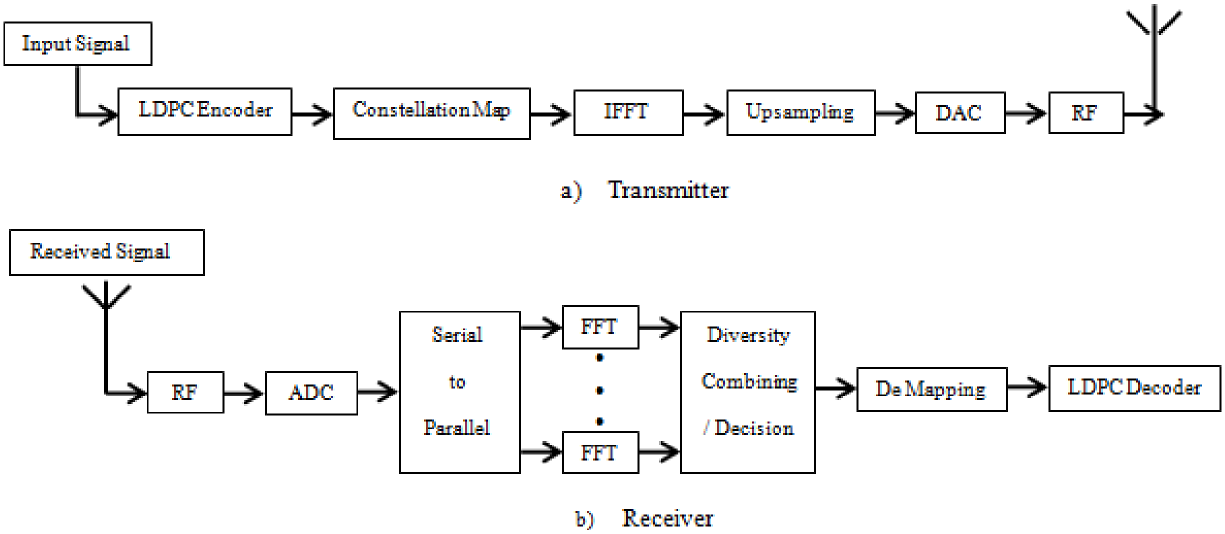

Fig. 1 System Model for the proposed LDPC-Pulsed-OFDM System

II. PULSED-OFDM-SYSTEM

In the pulsed-OFDM scheme [1], the pulsed-OFDM signal can be generated by up-sampling the digital baseband OFDM modulated signal before sending it to a conventional DAC. The up-sampling is done by inserting K"1 zeroes between samples of the signal. The resulting pulsed-OFDM signal is then a pulse train with a duty cycle of 1/K. The up-sampling factor K needs to be smaller than or equal to an upper limit K_{max} given by (1), where ω is the sub-band bandwidth, B_c *is* the coherence bandwidth of the channel, and T_{spread} is its maximum delay spread. For a given channel, the optimum K is in the range $K = 1, \ldots, K_{max}$.

$$K_{max} = \left\lfloor \frac{\omega}{B_c} \right\rfloor = \left\lfloor \omega T_{Spread} \right\rfloor \qquad (1)$$

In the multiband-OFDM (MB-OFDM) approach [5], [6], the available UWB spectrum is divided into several sub-bands of smaller bandwidth. An OFDM symbol is transmitted in each sub-band, and then, the system switches to another sub-band. Quadrature phase-shift keying (QPSK) modulation is used for OFDM. The transmitted signal in this scheme is given by

$$x(t) = \sum_{r} \sum_{k=0}^{M-1} b_k^r e^{j2\pi k f_0 t} p(t - rT_p) e^{-j\frac{2\Pi C(r)t}{T_S}} \qquad (2)$$

Where 'M' is the number of subcarriers in each OFDM symbol, and $p(t)$ is a low-pass pulse with duration T_p. The QPSK symbol that is transmitted in the 'r_{th}' time slot and over the k_{th} subcarrier is denoted by b_k^r. The subcarrier spacing is denoted by f_0 and is equal to $1/T_p$. Sequence $c(r)$ controls frequency hopping between sub-bands. The MB-pulsed-OFDM signal can be presented with a similar formula as the MB-OFDM signal in (2). Here, p(t) is a train of pulses with duty cycles less than one [1], i.e.,

$$p(t) = \sum_{n=0}^{N-1} s(t - nT) \qquad (3)$$

Where s(t) is a monopulse width duration T_s, and 'T' is the pulse separation time, which is larger than T_s. The number of monopulses is denoted by N and is the same as the number of subcarriers for the OFDM modulation. This number will be chosen, such that the total bandwidth of the pulsed-OFDM signal becomes equal to that of the non-pulsed-OFDM signal [1].

III. LDPC-PULSED-OFDM

LDPC codes are a class of linear block codes developed by Robert G. Gallager in 1963. LDPC codes have easily parallelizable encoding and decoding algorithms. The parallelizability is 'adjustable' providing the user an option to choose between throughput and complexity. The function of the encoder is to add extra redundant data for given uncoded data. This extra redundant data, called as parity data is useful in detecting the errors that are introduced during the data transmission through a channel. LDPC encoder along with BCH encoder block is used for generating the parity data in DVB-S2 systems. In this approach, the parity-check matrix of the LDPC code with code rate R is obtained from the from the DVB-S2 standard.

A. System Parameters

To transmit information, the Pulsed-OFDM system uses convolutional coding and puncturing to achieve a rate of 2/3, followed by OFDM modulation with M = 32 subcarriers. In the LDPC-Pulsed-OFDM system LDPC codes are used to achieve a specific code rate, followed by OFDM modulation. Fig.1 shows the new system Model for the proposed LDPC-Pulsed-OFDM System transmitter and receiver. The input signal is assumed to be scrambled and is fed to the LDPC encoder. The encoder used 100 iterations to encode the scrambled input signal. QPSK mapping sets the constellation points for the encoded symbols, to find error detection

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and correction. The signal is then passed through a serial-to-parallel converter to separate the diversity branches. Each branch is separately demodulated using FFT algorithm. A 32-point IFFT is used at the transmitter followed by up-sam pling with a processing gain of K = 5. Similar to other OFDM systems, a cyclic prefix (CP) is added after the IFFT at the transmitter and discarded from the received signals before the FFT in each branch eliminates inter-symbol interference and inter-channel interference in all branches. At the receiver, the diversity branches are combined using equal gain com bining followed by constellation de-mapping and LDPC de-coding

B. System Performance

To compare the performance of the LDPC-Pulsed-OFDM and Pulsed-OFDM systems, a complete simulation of the system over the channel models described in the IEEE 802.15.3a UWB channel modeling report [7] is done. Here, the simulation results of CM3andCM4 channels at extreme fading conditions are presented. Fig. 2 (a) to (d) shows the results over the CM3 and CM4 channel under log normal fading conditions. In this figure, the bit error rate is plotted versus the signal-to-noise ratio for both channel model. The simulation results showed that the LDPC-Pulsed-OFDM system performance is stable for different code rates and achieves a BER nearly 10^{-5} for SNR up to 6dB using QPSK. The performance of LDPC-Pulsed-OFDM is better in additive white Gaussian noise (AWGN) channel

C. Power Consumption

The power consumption of a very-large-scale-integration (VLSI) chip is determined by its clock rate and the supply voltage and capacitance of the circuit. As the numbers of components are reduced, the power consumption of the VLSI chips will be less. The system provides lower complexity and power consumption compared to the existing baseline system.

D. Channel Parameters

The IEEE 802.15.3a UWB channel parameters that is used for the simulation is given below in Table 1

TABLE 1:- IEEE 802.15.3A UWB CHANNEL PARAMETERS

Model Parameters	CM3	CM4
Λ [1/nsec] (cluster arrival rate)	0.0667	0.0667
λ [1/nsec] (ray arrival rate)	2.1	2.1
Γ (cluster decay factor)	14.00	24.00
γ (ray decay factor)	7.9	12
σ1 [dB] (stand. dev. of cluster lognormal fading term in dB)	3.5	3.5
σ2 [dB] (stand. dev. of ray lognormal fading term in dB)	3.4	3.4

IV. SIMULATION RESULTS

The performance of LDPC codes is measured in terms of bit-error probability versus signal-to-noise ratio. The simulation results of LDPC-Pulsed-OFDM for the different code rates supported by LDPC DVB-S.2 standard are presented. The proposed system is analyzed for UWB indoor propagation channels CM3 and CM4 under log normal fading with the code rates 2/5, 1/2, 2/3 & 3/4. The log normal fading characteristics incorporate the worst channel conditions possible. The simulation results in Fig.2 (a) to (d) show that the LDPC-Pulsed-OFDM system achieves a bit-error-rate nearly 10^{-5} for the above indoor channels. The frame size of 300 and 256 bits per block is used for all of the above code rates under extreme line of sight channel conditions. SNR of 6-8dB is achieved for CM3 and SNR of 4dB for CM4 using QPSK. Higher values of SNR can be achieved by using different modulation schemes.

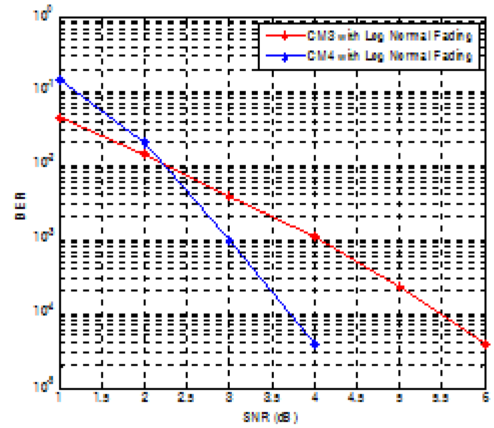

Fig.2 (a) LDPC Pulsed OFDM CM3 and CM4, Code Rate 2/5

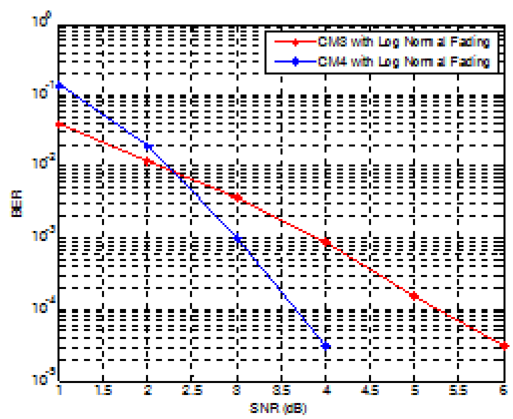

Fig.2 (b) LDPC Pulsed OFDM CM3 and CM4, Code Rate 1/2

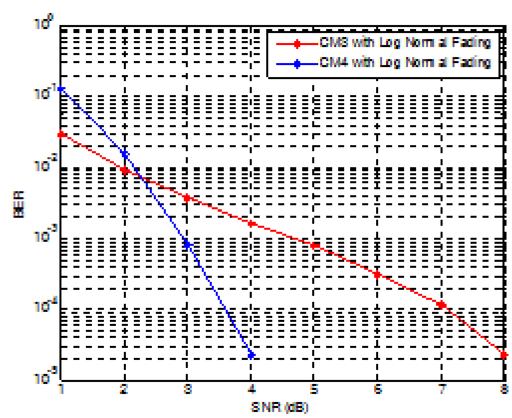

Fig.2 (c) LDPC Pulsed OFDM CM3 and CM4, Code Rate 2/3

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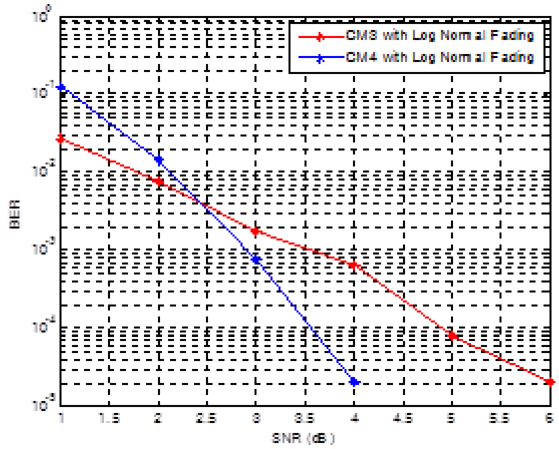

Fig.2 (d) LDPC Pulsed OFDM CM3 and CM4, Code Rate 3/4

V. CONCLUSION

LDPC-Pulsed-OFDM is a combination of the benefits of LDPC codes and pulsed-OFDM, utilizing the ultra-wideband spectrum to efficiently achieve a comparable performance under different code rates and has achieved a bit-error-rate nearly 10^{-5}. The system provides frequency spreading and diversity in multipath fading channels. By replacing the convolution encoder and puncture in the Pulsed-OFDM system and using LDPC encoder, we designed a system for the WPAN utilizing the UWB channel conditions with reduced complexity, reduced power consumption. Since, QPSK is used, the maximum achievable SNR is 6dB to 8dB. To enhance SNR up to 16dB for different code rates , amplitude-phase shift keying (APSK) could be used . Also, data rates of more than 1Gbps could be achieved using MIMO.

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